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Microelectronic Grade Silicone Materials for CSP

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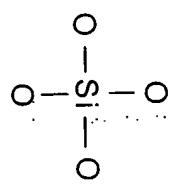
Outline

- The nature of silicones
- Silicone polymerization
- Root cause of silicone outgassing
- Development of materials for use in the μ BGA package
 - Resolution of Lead bond issues
 - X-ray Photoelectron Spectroscopy images
- Conclusions

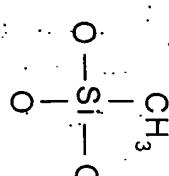
Chemical Nature of Silicones

Degree of Alkyl Substitution

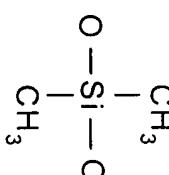
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SiO_2

Silica

Glasses

$\text{R}_1\text{SiO}_{3/2}$

Silicone resins]

R_2SiO

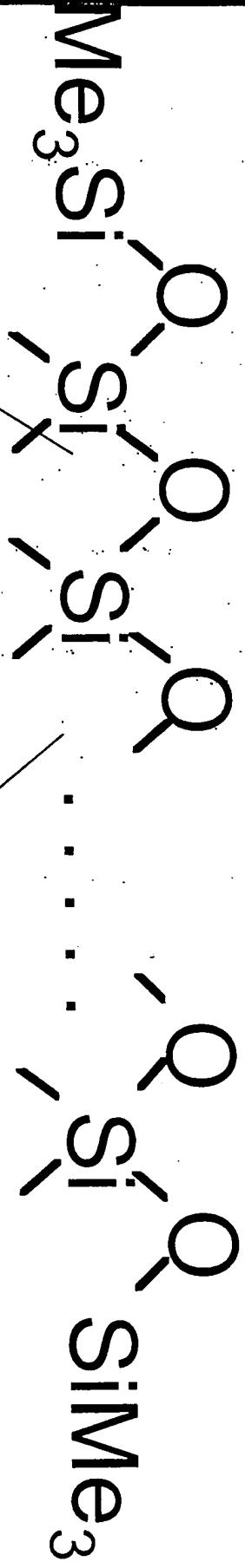
Silicone

Silsesquioxanes
polymers

Hard & Brittle

Soft & Flexible

Properties of Silicone Fluids



- Wide OSiO angle \Rightarrow Free rotation, low Tg, Tm, etc
- Strong Si-O Bond \Rightarrow High Thermostability
- PDMS backbones are covered by CH_3 's, hydrophobicity

Silicone Properties*

- Liquid at high molecular weight
- Low apparent activation energy for viscous flow
- Low surface energy
- High gas permeability
- High dielectric strength
- Thermal stability
- Oxidative resistance
- Low boiling points
- Excellent flammability
- Low surface shear viscosity

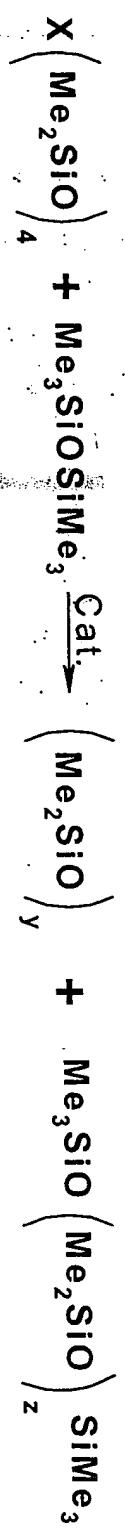
* Relative to hydrocarbon materials

Equilibration Polymerization of Silicones

- Acid or base catalysis
- Time, temperature and solvent effects
- Molecular weight control
 - End block
 - trimethylsilyl
 - dimethylhydroxyl
 - dimethylvinyl
 - others

Equilibration Polymerization of Silicones

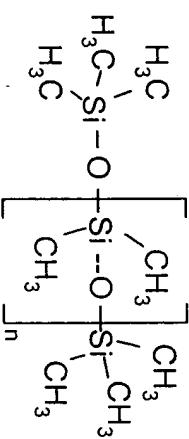
- Polymerization:



- Equilibrium mixture of cyclics and linears
 - High Mw linear polymer
 - Typically 11-18 wt. % cyclics for PDMS
- Low molecular weight species are very volatile and low viscosity

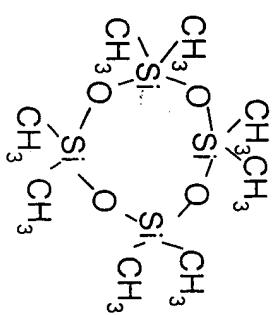
LOW MW Silicones

Compound	Viscosity @ 25 C cS	Boiling Point C	Mw
Water	1.0	100	18
MIM	0.7	101	162
D ₃		135	222
MDM	1.0	153	237
D ₄	2.3	175	297
MD ₂ M	1.5	196	311
D ₅	3.9	211	371
MD ₃ M	2.1	230	385
D ₆	6.6	245	445
MD ₄ M	2.6	260	459
D ₇	9.5	276	519
MD ₅ M	3.2	287	533
D ₈	13.2	303	593
MD ₆ M	3.9	310	607
D ₉	18.0	326	667
MD ₇ M	4.5		681



M (D)_n M

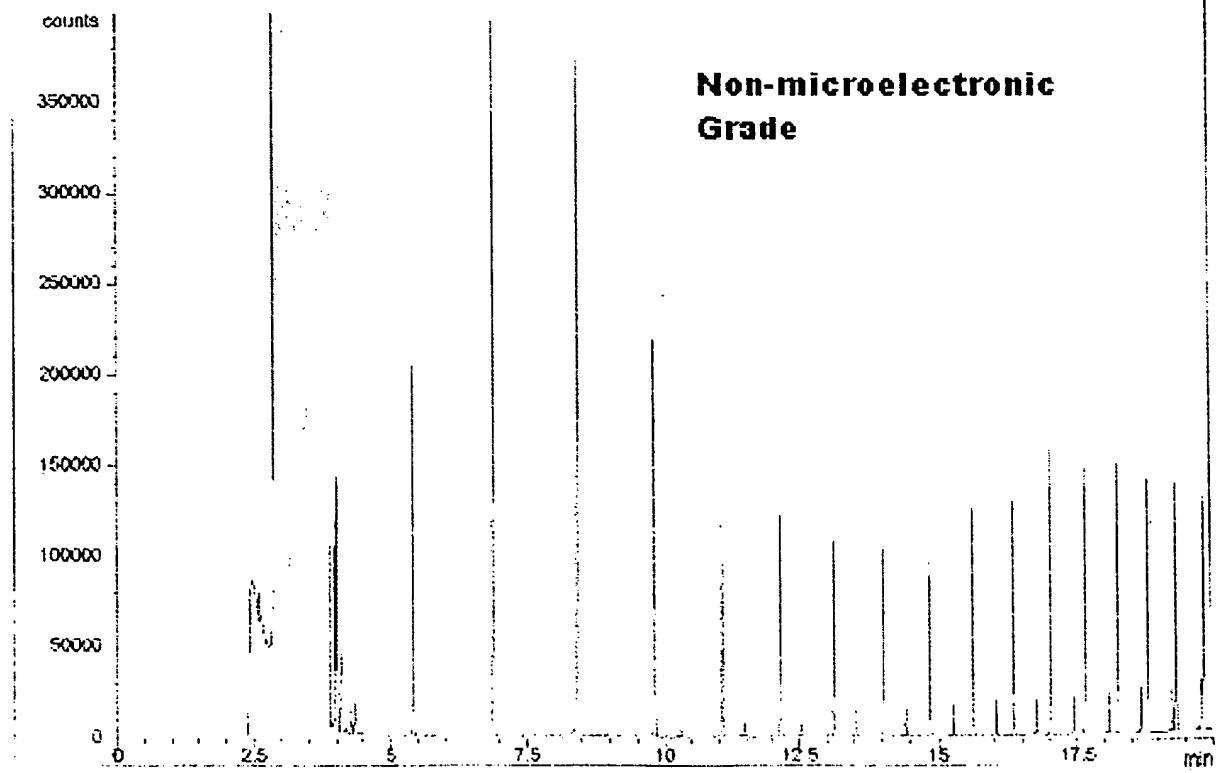
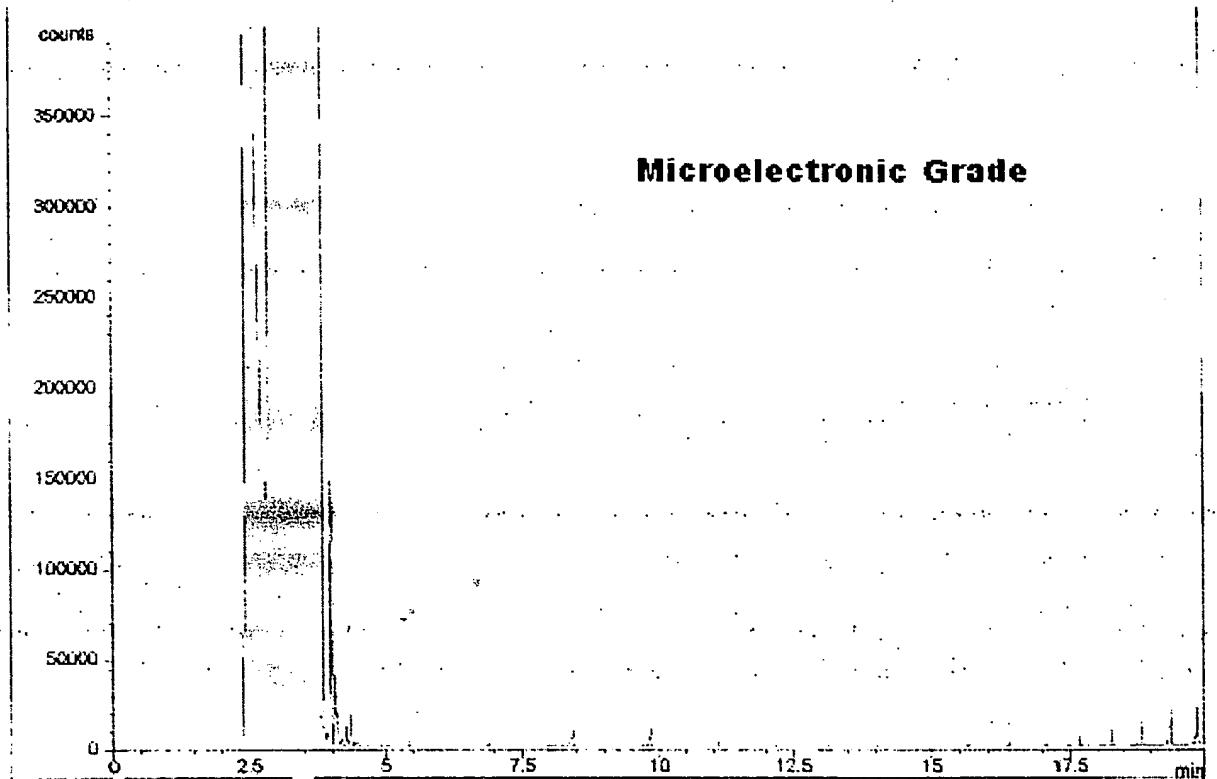
Linear series



D₄
Cyclic series

Removal of Low Mw Species

- Vacuum strip dependent on:
 - time, temperature, vacuum level
- Liquid-liquid solvent extraction
- Non-solvent precipitation
- Super critical fluid extraction
- High pressure liquid chromatography



Gas Chromatography

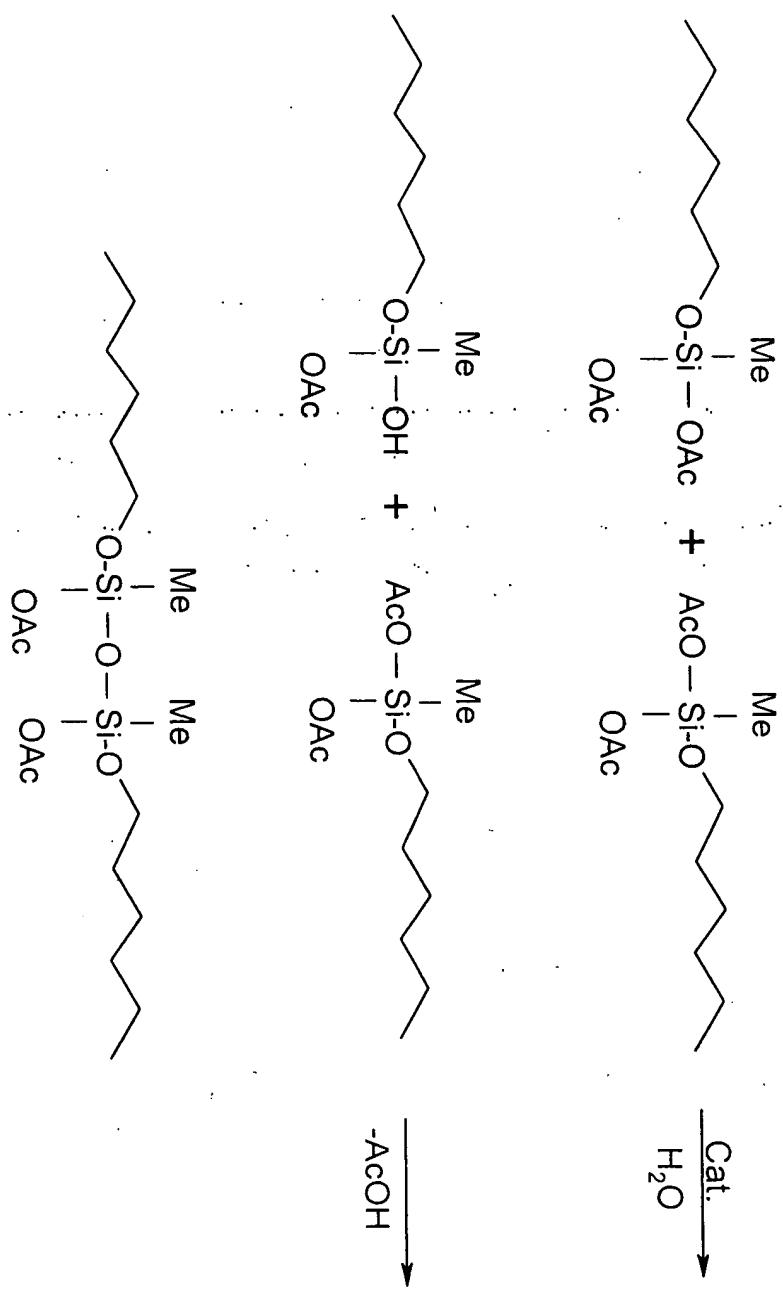
Compounds	Non-	Microelectronic
	microelectronic Grade	Microelectronic Grade
	PPM	PPM
D4-D12	20600	0
D13-D20	11860	734

- Greater than 95% reduction in low Mw species
- Remaining material is high Mw
 - high viscosity & high boiling

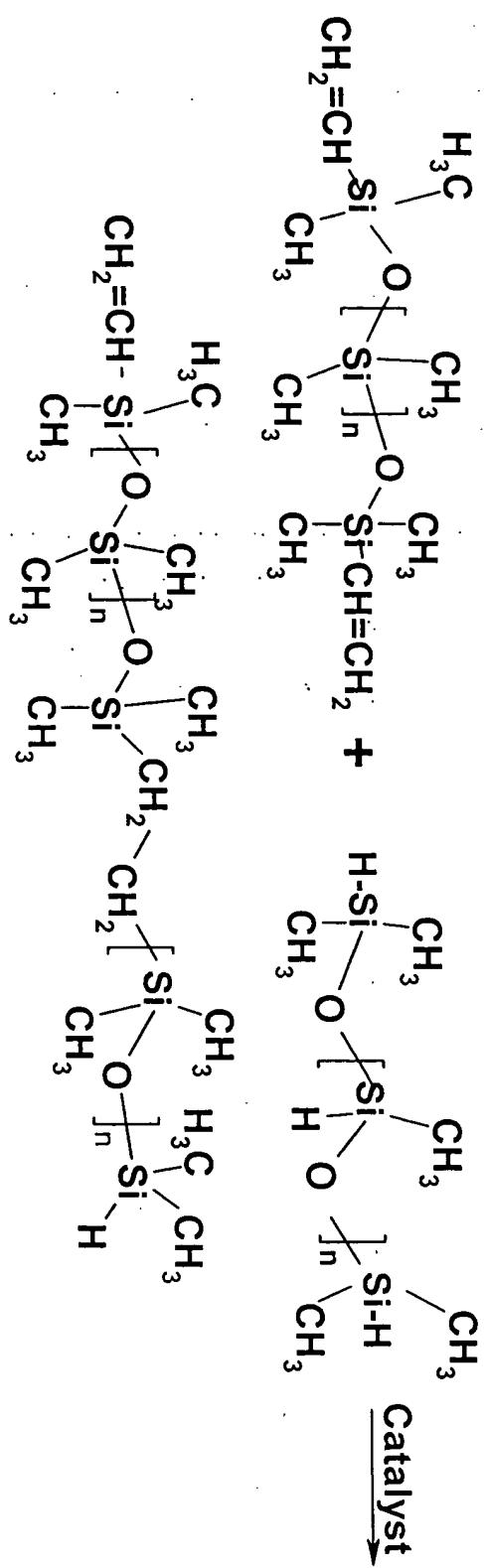
Typical Silicone Formulation

- Silicone polymer
 - outgassing
- Filler
- Crosslinker
- Adhesion promoter
- Catalyst (Pt)

Condensation Cure

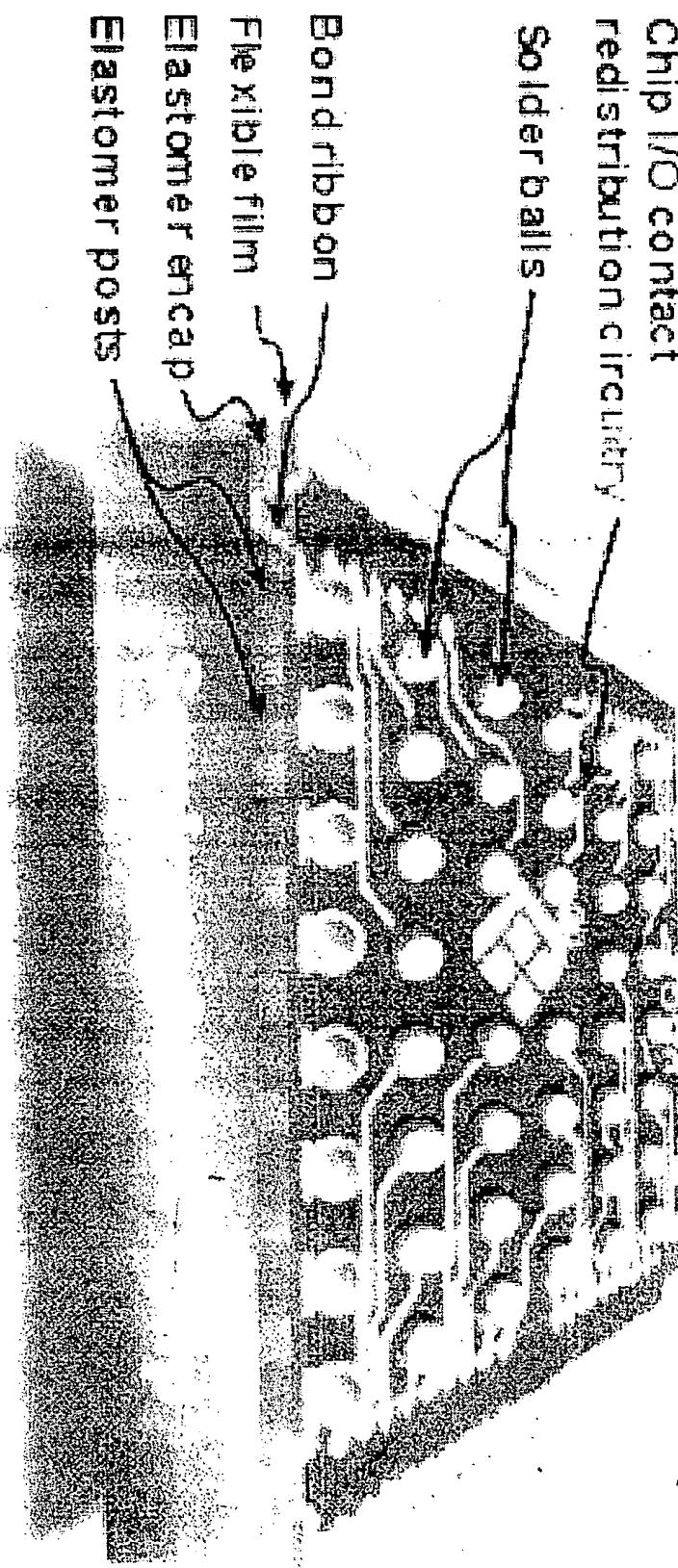


Addition Cure



- No cure by-products
- Heat activated
- Can be 1-part or 2-part

μ BGA Package



Material and Process Considerations for CSP Lead Bonding

- Design considerations
 - Nubbins or pads
 - Proximity to lead bond area
- Material considerations
 - Rheology
 - Low volatility
 - Low creep
- Off set stencil printing
 - Gross contamination during printing
 - Time between print and cure

Non-microelectronic grade materials led to:

- Migration of silicone onto leads
 - Cure silicone nubbins
- Self diffusion of low Mw components
 - $D \propto 1/M_w^2$
- Surface spreading
 - $\eta \propto M_w$
- Outgassing

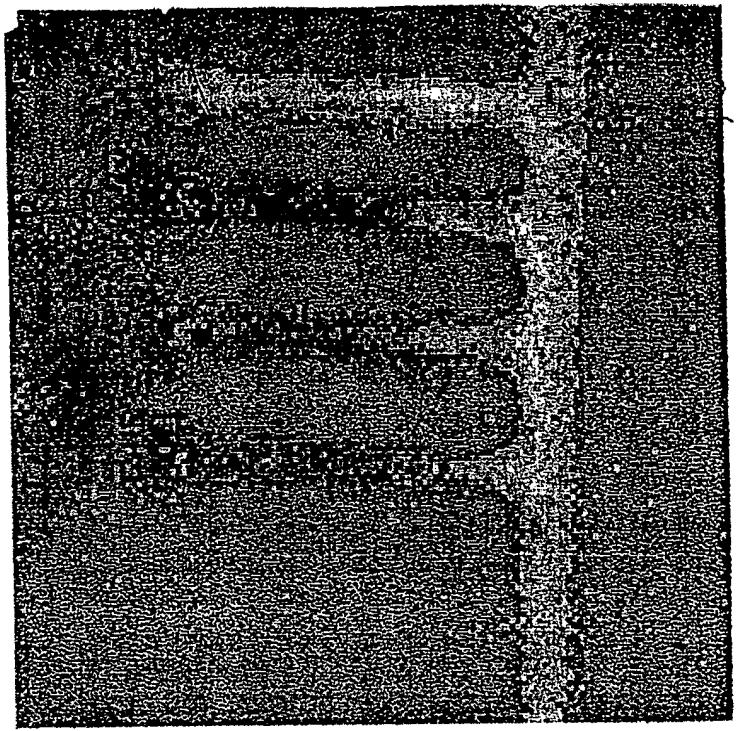
Use of non-microelectronics grade silicones led to increases in:

- Lead bond ultrasonic frequency
- Cleaning frequency of lead bond tip
- Deformation of the lead
- High failure rate due to heel breaks

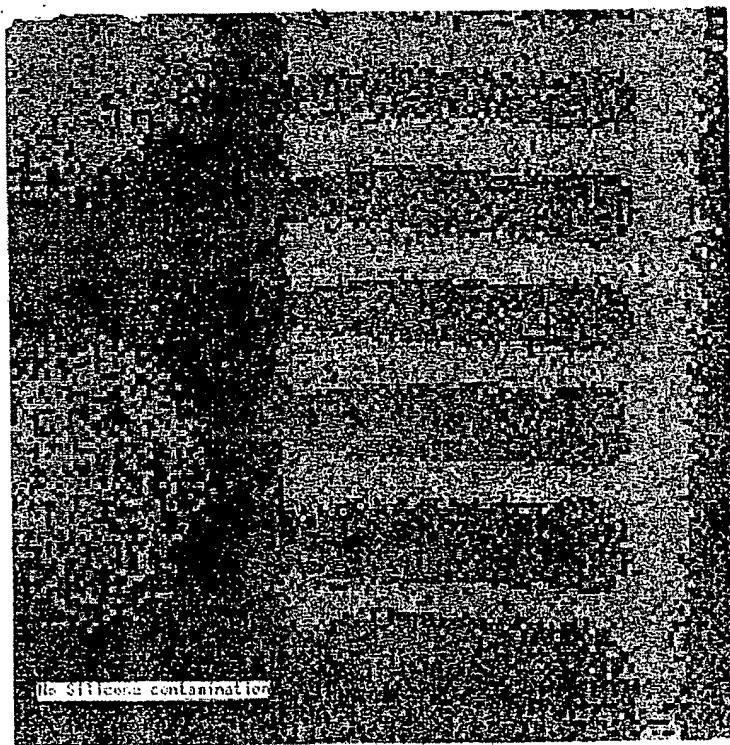
Microelectronics grade silicone
material eliminated all problems:

- Increased yield
- Increased productivity
- Increased reliability

XPS of TAB tape showing leads



Non-Microelectronic Grade Silicone



Microelectronic Grade Silicone

Summary

- Silicones have unique properties due to their chemical composition.
- Equilibration polymerization of silicones
 - Low M_w species present - root cause
 - Can be removed by further processing
- Not all silicone materials are alike
- Low outgassing microelectronic grade silicone material set is commercially available.
- Companies are in production with μ BGA using a low outgassing silicone material set.

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